Sustainable Development Potential (SDP) of Indian Automobile Manufacturing Sector based on Circular Economy Principles: A Systems Modeling Approach

A

Synopsis

Submitted in the partial fulfillment for the requirement of

Doctor of Philosophy

In

Management

Submitted by

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2021

SECTION 1: Introduction

For billions of years, living organisms have been in existence on this planet without perishing to landfills, and it is certain that will exist for billion more managing zero waste. The reason for this is the circular nature of Biological cycle. Sunlight and rain acts as the source of nutrition for vegetation, which acts as the food for herbivorous animals, and they further become part of the all-pervasive food chain in the biological world. The animals upon death converts to fossils and nutrients which enhances the quality of soil and supports the vegetation. The cycle continues with no waste and sustainability is the outcome, which is been there for very long time and is there for times to come.

From the time it started to develop products, the linear principle of take, make and waste remained at the forefront of the human industrial endeavor. For a long period of time, natural elements remained primary source of material for product development, but with the advent of industrial revolution, new materials came into existence with enhanced durability and life, like plastics. The once indispensable linear paradigm is now leading to a new problem Waste. This is resulting into huge landfills, higher levels of pollution for air, water and land, to an extent that it is leading to an existential challenge to the human kind.

Besides toxic waste, finite resources and increasing population are posing more serious challenges to the industry, to develop products to limit the use of finite resources. From a long-term perspective this is a very alarming situation and we need to make changes in our Product life cycle to limit the use of finite resources. If we can adopt the biological cyclic nature in economic practices, then we can form the basis of new economical paradigm called Circular Economy.

1.1 Circular Economy

Circular Economy is an economical paradigm which is centric to turning the waste into capital. As opposed to the linear economy, circular economy focuses on reuse rather than waste, and hence addresses the dual problem of pollution and landfills due to waste and resource conservation [23-27].

There are various levels at which the basic principles of circular economy can be applied to get the desired outcome. By Rethinking and Redesigning the Products, components and Packaging, safe and compostable material can be developed. Non decomposable products like Electronics and Automobiles manufacturing processes can be redesigned for a longer life, minimizing waste and

recycling. Circular economy essentially aims at implementing a causally linked closed loop system which employs the recycling, repairing, refurbishing, reuse, sharing, remanufacturing, to have a sustainable and long- term usage of resources. To draw a parallel with biological systems, it is expected that all waste in a circular economy paradigm should become ingredient for some other process, or a regenerative resource [28-30].

Linear Economy	**Circular Economy**
It is a take make and waste paradigm, where the raw materials are collected, transformed into products and disposed as waste.	Follows 3R approach of reduce, reuse and recycle. Minimal resource utilization (reduce), products and its parts to be reused (reuse), and raw material to be recycled.
Value creation in this model done through increasing production and sale of products.	**Value creation** is done by preservation.
The focus of a linear economic model is on **eco-efficiency**. The ecological balance is to be retained for the same output, this will extend overloading period for systems. [17]	Sustainability is sought by improving the eco-effectiveness of the complete system. This not only impacts the **ecological balance**, but also has **positive social and economic impact**. [18]
Usage of the raw material is inefficient as the emphasis is not on the conservation.	Raw material conservation is in the focus and transition to product as service is one possible conversion from linear to circular model.[19]
Highly energy inefficient and poor energy reclaim rate.	Energy usage is reduced, and renewable resources are sought majorly.

1.1.1 Material Recycling, Reuse and Recovery in circular economy

The cyclical approach to manufacturing and resource management is particularly well suited to the mining and metals industry.

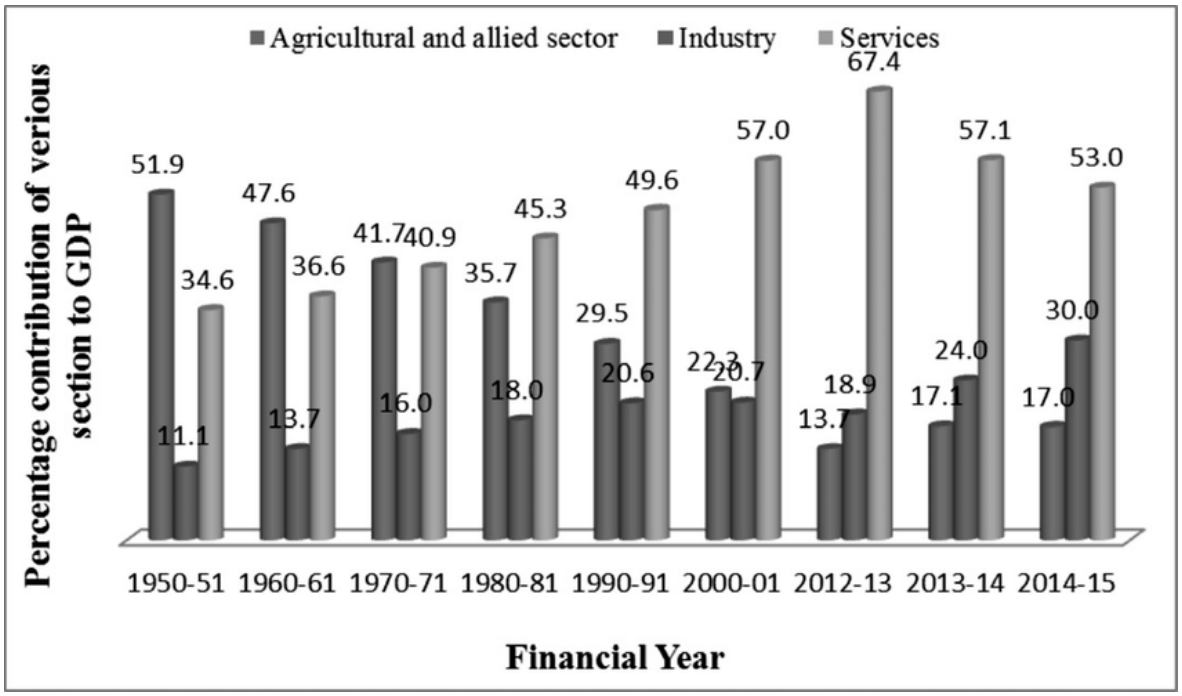
Metals are recyclable to a high extent, as their inherent durability, strength and anti-corrosive properties help to enhance the longevity of products in which they‘re used. The high value of many metals and minerals also incentivizes the recovery of such materials at the end of a product‘s life cycle, and hence there are many methods in place to facilitate their re-use and recycling.

1.2 Industry 4.0

Klaus Schwab the founder of World Economic Forum coined the term Industry4. Schwab quotes about I4, ―Technological revolution that is blurring the lines between the physical, digital and Biological spheres‖. Like CE , I4 is another leading area of research [31-33] where active work is happening and also changing the Technologies like AI, IOT and automated vehicles are becoming part of our day to day life. We have Alexa, Siri, Face Id recognition, Healthcare sensors, 3D Printing as new age innovations using I4. But I4 ALSO focus on Product Consumer and technology integration. It improves the Product and makes it more Customized by using advanced technologies like IOT. Implementing I4 requires Government, Industry and Academia collaborations.

1.3 Manufacturing Sector in India

Indian economy after independence has primarily been agrarian economy and the first decade post-independence had almost 50% dependence on the agriculture. In last few decades service sector has surpassed the agriculture sector and has become a major contributor in the Indian economy. The growth seen by the manufacturing sector in India is particularly not very impressive, and the relatively slower growth of the Indian economy as compared to other comparable economies of the World is typically attributed to the slow growth of the Indian economy. Fig. 1 [15] depicts the sector wise growth trends seen by the Indian economy, since Independence.



Appreciating the potentials of manufacturing sector as vehicle for growth of economy and generating organized jobs across large section of population, the Indian Govt has started to pay more attention to the fuel in the growth of the manufacturing sector [references on make India / GST / infrastructure]. Multiple steps to boost the growth of manufacturing sector from tax reforms, educational and infrastructure are being taken up.

Manufacturing sector in India has moved from foundation building in 1950‘s and early 1960‘s, to the license–permit Raj between 1965 to 1980. During 1990‘s it moved through liberalization and is in the phase of global competitiveness, today. The Indian Manufacturing sector currently contributes 16- 17% to GDP and gives employment to around 12% (2014) of the country‘s workforce. It is estimated that on average every job created in the manufacturing sector leads to 2-3 jobs in the service sector. For an inclusive growth, manufacturing is an important sector for a high population country like India, where the job creation is an important policy consideration. Manufacturing is thus rightfully at the center of India’s current policy of Make in India (MII), which is to increase contribution of manufacturing to GDP to 25%.

1.4 Automobiles Sector in India

The Auto & Auto Component industry’s impact on the Indian economy currently is significant as it contributes ~7% to the country‘s GDP and is expected to increase to 12% as per the Automotive

Mission Plan.

According to the Automotive Mission Plan 2016-26 (AMP 2026); a collective vision of the Government of India and the Indian Automotive Industry, the Indian Auto Industry will be in the global top three for engineering, manufacturing and export of vehicles, auto components; it will encompass safe, efficient and environment friendly conditions for affordable mobility by 2026.

The industry is likely to grow from 80 Billion USD to 270 Billion USD by 2026 and generate an additional 65 Million jobs. The Automotive industry is key to the domestic Manufacturing Sector contributing over 40% and impacting the fortunes of several related manufacturing industries such as Iron and Steel, Aluminum, Rubber, Chemicals, Molds etc.

The Auto industry, over the years, has adapted well to the changes in the policy & regulatory environment and the needs of its customers. In FY 14-15 the Indian auto-components industry bounced back growing at 11% and registered a turnover of USD 38.5 billion. Today, the industry contributes ~46% to the Manufacturing GDP and ~7% to National GDP, providing direct employment to 1.5 million people and is an important driver of growth for the Indian economy. Automobile exports too have grown despite the global slowdown, growing at 14.89% from April-March 2015 over the same period last year. [16]

1.4.1 New Directions towards Sustainability

Futuristic Sustainable Development in automobile sector must satisfy the needs of the present without compromising the ability of future generations to satisfy theirs. Sustainable development in auto sector of future will also imply the fulfillment of several conditions like preserving the economic and environmental balance by not only creating new jobs and economic opportunities but also rigorously working for the protection of the environment and preventing the exhaustion of natural resources.

The future of the automotive sector will be basically shaped by economic recovery, new innovative software and hardware technologies, electric vehicles or other alternative energy propulsion possibilities. It is also expected that the automobile industry will be forced to tackle spatial problems like parking and congestion, especially in urban areas. There are several new sustainable initiatives taken by the Government of India particularly with regard to emission norms and promotion of green and energy efficient auto products which will also be considered in the present study to ensure circular

economic compliance under holistic decision-making environment.

1.5 System Dynamics Modeling:

Systems thinking help decision makers to take holistic view of the problem situation in order to arrive at effective solutions and strategies. Automobile manufacturing being a sub-system/ component of the holistic circular economy system of India, can be characterized by a closed loop causal process of designing and developing a product, Production, Marketing and distribution, Usage, Abandonment, Re-use and Re-processing of the product. This implies the need for a holistic systems approach in sustainable decision making. It is the exact opposite to traditional approach practiced in most of the economic sectors. The traditional approach to problem solving is reductionist approach, which involves breaking down the whole system into internally manageable pieces and then analyzing each piece in isolation. This view is implicitly a linear view of management decision making, treating it merely as a sum of the behavior of its parts. The real behavior of a causal complex system however is more than just the sum of its parts, particularly under broader socio-economic-environmental contexts. In this regard, it is evident that in the nature of things, the variable/ component function of Circular Economic system‘ is interrelated and hence needs holistic and coherent handling, both from decision makers as well as consumers perspectives. In brief, because of the interrelationship among the different influencing variables and their dynamic complexities, it would be necessary and desirable to look at the circular economic system driven automobile manufacturing as a single unified system and optimize the efficiency of decision making as a whole. This is precisely what an applied ―Systems Modeling Approach means. Such an approach will facilitate better and insightful understanding about the dynamics of various auxiliary functions and influencing variables effecting decisions in the Indian automobile industry.

In the above context, System Dynamics is a popular Systems Modeling technique which is used to capture and analyze the inherent dynamics of any complex systems, issues and problems. System dynamics is an aspect of systems theory as a method to understand the dynamic behavior of complex systems. System Dynamics is a computer-aided approach to ‗what if‘ policy analysis and design. It applies to **dynamic** problems arising in complex social, managerial, economic, or ecological **systems**—literally any **dynamic systems** characterized by interdependence, mutual

interaction, information feedback, delays and circular causality among the constituting components of a system.

SECTION 2: Literature Review

M. Lieder and A. Rashid in [1] have presented a comprehensive review and analysis of prevailing research in the area of circular economy. There are two important conclusions which are presented in the paper –

a. In general, the research in CE is focused on waste generation, resource use and environmental impact, while the business and economic perspectives are neglected. They further concluded that the advantage for industry seems inexplicit, which may be an inhibition for CE implementation. To avoid biased interpretation of CE concept, they have discussed a comprehensive system-oriented framework taking into consideration
   i. Waste and environment for minimal environmental impact.
   ii. Regenerative use of resources
   iii. Economic viability for industrial acceptance
b. The paper also concludes that there is a need for comprehensive top-down and bottom-up approach to keep the interest of all stakeholders like Society, Government, manufacturing industry, etc.

The model they have presented is a primitive systemic model but points out a systemic approach is way forward to have a successful CE implementation. **J. Ruiz-Real et al. in [2]** have provided a bibliometric analysis of research publications across the World in the period 2006-2017, and concludes the following –

a. Governments across the world are seeing CE as a philosophy and strategy to achieve clean growth amidst tighter environmental goals.
b. CE is impacting the management of companies in waste management, recycling and reuse in the plastics economy, food, fashion, design, etc. There is still a need to define better the areas and sectors that fall within the scope of CE.
c. CE and Environment are very closely linked in the academics. Have also discussed that CE is also acting as a very popular area of research amongst scholars. China is the world leader in CE

research.

The research presented in this paper outlines very clearly that CE is a trending topic and is very closely related to environment. With the pollution and waste management norms getting stringent, in countries like India it is imperative that research on CE applications is inevitable. **R M DEUS et al. in [3]** have presented a bibliometric analysis of existing research in the area of circular economy. They have two noteworthy conclusions –

a. China is a world leader in publications on CE. It is also acting as the leader in establishment of indicators for CE.
b. There is still a requirement of research on CE to grow to a level to make significant global, socio-economic, environmental and political impact. There is a need to study sub-sectors for the application of CE.

O. Okorie et al. in [4] presented a comprehensive literature review of digitization technologies, notably I4.0. They have pointed that currently I4.0 and CE as paradigm of research take independent direction in research and there is a need for integrated CE I4.0 research, as during the period of review (2012-2018) very limited integrated research is been done. A categorization for the future trends on CE I4.0 integrated research is presented in perspective of different stakeholders viz. academia, industry, policy makers and end users. An integrated framework for future research is developed in the research utilizing the technology life cycle (TLC) framework. An important outcome of the study is that the end users or consumers are not captured clearly in the current CE research and framework. A clear need for a synthesized integrated framework in CE and I4.0 as front running digitization technology, that includes all stakeholders is posed by the research. A comparison is presented between the integrated framework and ReSOLVE framework, but its suggested that for future research both frameworks should be utilized. It is further recommended that micro-units of circular approaches using 9R‘s should be researched, and this can produce very good results for industry. **In [5] Vanessa P S, Carmen Jaca and Marta O** have presented a consensus-based CE framework to formalize the main aspects of CE and explain its relationship with eco-innovation. They have pointed out the four main components of CE, as 1) resource and energy recirculation, 2) multi-level approach 3) sustainability to development 4) relationship to how society innovates. These aspects of CE definition allow the

stakeholders to come to a consensus on CE. The authors in this paper have highlighted the role of eco-innovations as a basis of creating a CE. **In this work [6] Shulin Li** has established a quantitative evaluation model based on input-output analysis tools. This model can be used to develop a primitive related evaluation index for circuilar economy development, by describing waste output, consumption in a period of time and exchange and releases in production. It is claimed that as compared to general model of evaluation of CE, the benefits resulting from reduction in elimination of waste can be analyzed using this method and hence have amore significant effect on the quantitative analysis of circular economy. This is a primitive attempt towards modelling the impact of various aspects on the CE but opens possibilities of mathematical modelling for quantitative analysis of the performance of CE. **T. Lahti, J. Wincent and V. Parida [7]** have presented a theoretical review of value creation and implementation of next generation business models. They have discussed various aspects of defining circular business models and circular economy. This is the baseline work for the development of the models for circular economy as they have discussed in detail the theoretical perspectives and the key problems which are there to be addressed for transforming a business from linear economy model to circular economy. Overall there is a lot of uncertainty due to consumer behavior for the companies that want to enter the circular economy with new business models to address sustainability. The absence of value chain or value delivery mechanism adds to the concerns of such businesses. Overall, it is suggested from the study that the businesses or companies which are interested in sustainable development using circular principles will have a potential to stake a claim on their markets, which might lead to long-term profits. There are clearly a lot of research opportunities in various businesses which are needed both to generate interest and gain confidence of industry into CE. **This report [8] by Ellen McArthur foundation** is a pioneering work of research on the possibility of circular economy and its impact on India. In this report three major sectors of Indian economy viz. food and agriculture industry, infrastructure and construction, and transportation and mobility and vehicle manufacturing industry. Some if the indicators from the report shows that adopting circular economy can lead to 11% saving in India's GDP by 2030 and 30% by 2050. One of the most important sectors which India has to focus on is the vehicle manufacturing. With the increasing Indian population, the demand for personal mobility can increase to almost double by 2030. It is imperative that both in the business

models and manufacturing, linear principles are not going to be sustainable. **M. Lieder et al. [9]** outlines a quantitative analysis tool for decision making on product design, supply chain and business models and is capable to connect end-to-life design with business strategy. To mitigate the uncertainty in evaluating the design and business approaches, the model proves very useful. There are two aspects of the work done in this paper –

a. Quantification method for the design efforts for different circular design options.
b. Multi-Method model for closed-loop manufacturing systems, combining agent-based and discrete event simulation.

This quantitative approach for modeling and factor analysis, is the way to move forward to mitigate the uncertainty on the adoption of circular design and business approach. **N R Yaduvanshi, R Myana and S Krishnamurthy in [10]** have discussed case of circular economy in India focusing on various facets of circular economy. In this article **[11] A Elmahdi et al**. using multiple case studies, have discussed the system dynamics modelling approach for socio-ecological systems. They have discussed various software and approaches for system dynamics modelling and also the best practices for systems modeling in general. They have strongly recommended systems dynamics as a modelling technique because of its meticulous representation of system feedbacks. **Maria A. Franco in [12]** discusses closing and slowing the resource loops in a circular economy, by means of system design models. This research helps developing insight into the impact of product design considerations at the inception of the product design and their impact on the product's take back stage at the onset of new manufacturing cycle. This work further presents the considerations of time delays and reinforcing feed-back loops in the design of an effective closed-loop supply chain. The ideas are practically put forward by means of system dynamics computer simulations. **Andre Nogueira et al [20],** have developed a new framework utilizing participatory action research methods in industry, ecology and design. They have argued that it's important to enable soft infrastructure in parallel with the hard infrastructure for material recycling, for a more inclusive CE implementation. **Deborah Sumter et al [21],** have presented a conclusion that the tools for circuilar economy implementation and analysis may go beyond systems thinking and CE might emerge as an independent field of research and analysis under sustainability. Their findings are based on multiple discussions they did with CE

professionals and feeding them to general competencies framework. These findings may open up new horizons for CE beyond systems thinking also, though these studies are in very preliminary stage. **Sadhan Ghosh [22],** has presented how resource consumption is minimized with rational use based on 3Rs, legislative framework and government supports towards implementing CE initiatives, example of best practices, future plans and targets in different countries those are helpful for researchers, planners and implementers. **Han J et al. in [43]** have discussed a study done on Hyundai Automotive Enterprise, where the loops of circular economy are employed. They have shown that servitization increases the product lifecycle in a circuilar economy and it re-emphasize that the products history is not linear but a combination of trajectories. The study presented in this paper are claimed to be impactful for business models oriented to circuilar economy. In particular, products can become services, leading to the establishment of new businesses and the creation of circular supply chain jobs. In particular, products can become services, leading to the establishment of new businesses and the creation of circular supply chain jobs. **Rohit Agarwal et al in [44]** have provided strong arguments in the favor of CE adoption in Indian automobile industry. Automobile is a resource intensive segment and leads to lot of energy and water consumption. End of life usage of non-bio degradable and manufacturing waste leads to environmental hazards. An extensive review from literature is done and 20 roadblocks are identified in the adoption of CE models. 'Lacking ability to deliver high quality re-manufactured products' is found to be the highest ranked roadblock. This is a landmark study in research on CE and Indian automotive industry. **S H Yuan in [45]** has discussed reverse logistics as an important support of developing circular economy. In this work the recycle of disabled automobile replacement parts are employed as research objects, and its been studied and the authors tried to establish the recycle system of disabled automobile replacement parts industry represented by the integration pattern of automobile manufacturers. This system not only conforms to the Extended Producer Responsibility (ERP) policy put forward by the government to the automobile manufacturers, but also can combine numerous enterprises and individuals. Study presented by **Kalverkamp M, Raabe T [46]** contributes to the understanding of remanufacturing marketing systems and policymakers and marketers can get valuable pointers from the same. Remanufacturing in automative is a specific circular marketing system of reuse, but supply shortage challenges the markets

in European perspective, going beyond the existing micromarketing perspective the authors have provided an account of macro-perspective of the European marketing system for supply and procurement, and better highlighted the inefficiencies. Asset management is turning out to be a new business mode, **Estarrona, Unai et al. in [47]** have provided an account of the challenges faced by assert providers in a circular economy. Servitization is becoming a common practice, whereby customer do not buy assets but pay for availability and reliability. In the study it is established that for asset management the biggest challenge is the management of assets which are available at the customer premise, it has to be clearly established the remaining life and state of the machines and their maintainability schedules. This is making IOT a natural choice for servitization towards circular economy. Towards the tide of electrical vehicles in the automotive sector, **Ahuja Jyoti et al. [48]** have provided a focused study which highlights the need for policies to prepare for appropriate management of electric vehicle (EV) lithium-ion batteries. This is in perspective of circular economy reducing the waste. Comprehensive literature review on circular business models and circular business model innovation is **presented in [49, 51]**, this focuses on review of the literature for economic viability of circular business models. Conceptual framework is synthesized for circular business model and circular business model innovation.

Sno	Authors	Year of Publication	Focus of Research
1.	M Lieder and A Rashid	2016	Presented a comprehensive review and analysis of prevailing research in the area of circular economy. They have drawn very important conclusions – i. There is consider confusion on economic viability of circular design. ii. Need of top-down and bottom-up approach to keep the interest of all stakeholders. Presented a primitive systemic model towards circular economy implementation.
2.	J. Ruiz-Real et al	2018	Provided a bibliometric analysis of research publications across the World, between 2006-2017. They have concluded the following – i. Governments See CE as philosophy for clean growth. ii. More areas to be featured in CE, currently the focus is on waste management, fashion, food processing, etc. iii. Close link in CE and environment in the literature can be seen, and it is acting as a trending research.

3.	R M Deus et al	2017	Presented a bibliometric analysis of existing research in the area of circular economy. There are two noteworthy conclusions – i. China is a World leader in the publication of CE and also in establishing the indicators of CE. ii. A clear requirement of research in CE to grow to a level where it can make significant global, socio-economic, political and environmental impact. iii. Need arise for studying sub-sectors for CE application.
4.	O. Okorie et al	2018	Presented a comprehensive review of digitization technologies notably I4.0 They have presented some important conclusions – i. CE and I4.0 are studied independent of each other and very less integrated study is taken place. ii. Utilizing the TLC(Technology Life Cycle) concept, an integrated framework is developed, which led to an important outcome that the end user are not considered as an integral part of CE research. iii. Comparison between the presented research and ReSolve framework is provided, it is indicated that the future work should consists of both models
5.	Vanessa P S, Carmen Jaca and Marta O	2018	Presented a consensus-based CE framework to formalize the main aspects of CE and its relations with eco- innovations. They have highlighted the role of eco-innovations as a basis of creating a CE.
6.	Shulin Li	2012	Established a quantitative evaluation model based on input-output analysis models. A primitive CE development evaluation model is presented \, based on the waste output. This is a very simplistic model but open up thought for more complex models for CE evaluation.
7.	T. Lahti, J. Wincent and V. Parida	2018	Presented a theoretical review of value creation and implementation of next generation business models.
8.	Ellen McArthur Foundation	2016	Presented a focused research report on the present state of Indian economy and prospects of implementing circular economy in various sectors of India.
9.	M Lieder et al	2017	Outlines a quantitative analysis tool for decision making on product design, supply chain and business models and is capable to connect end-to-life design with business strategy.
10	N R Yaduvanshi, R Myana and S Krishnamurthy	2016	Discussed case of circular economy in India focusing on various facets of circular economy.
11.	A Elmahdi et al	2017	Using multiple case studies, have discussed the system dynamics modelling approach for

			socio-ecological systems.
12.	Maria A. Franco	2019	Discusses closing and slowing the resource loops in a circular economy, by means of system design models.
13.	Andre Nogueira et al	2020	Developed a model for considering and allocating the variety of resources that organizations utilize when creating value for themselves, society, and the planet.
14.	Deborah Sumter et al	2020	Presented that system dynamics might require more changes to be able to very closely model CE. Yet, it is a closest modelling technique.
15.	Sadhan Ghosh	2020	Presents how resource consumption is minimized with rational use based on 3Rs, legislative framework and government supports towards implementing CE initiatives.
16.	S. H. Yuyan	2010	Discussed reverse logistics as an important support of developing circular economy. In this work the recycle of disabled automobile replacement parts are employed as research objects.
17.	Kalverkamp M, Raabe T	2018	Contributes to the understanding of remanufacturing marketing systems and policymakers and marketers can get valuable pointers from the same.
18.	Estarrona, Unai et al.	2019	Asset management is turning out to be a new business mode, authors in [47] have provided an account of the challenges faced by assert providers in a circular economy.
19.	Han J. et al	2020	Discussed a study done on Hyundai Automotive Enterprise, where the loops of circular economy are employed
20.	Rohit Agrawal et al.	2020	Provided strong arguments in the favor of CE adoption in Indian automobile industry. Automobile is a resource intensive segment and leads to lot of energy and water consumption.
21.	Jyoti Ahuja et al.	2020	Provided a focused study which highlights the need for policies to prepare for appropriate management of electric vehicle (EV) lithium-ion batteries. This is in perspective of circular economy reducing the waste.
22.	Parida, V., Wincent, J and Martin Geissdoerfer et al.	2020	Comprehensive literature review on circular business models and circular business model innovation is presented

SECTION 3: Research Gaps

Through the above review of literature, we can draw the following conclusions –

1. Linear business and manufacturing models are not sustainable, and a paradigm shift in the Government policy, technology, business models and consumer consciousness is required

towards circular economy, which is inarguably targeted towards resource conservation and sustainability of development. This is in tandem with stringent environmental norms which are part of international policy in recent times. **[1, 2, 3, 4, 5, 22, 48]**

2. The research in circular economy is mostly tuned to decision making in waste management, recycling and reuse in the plastics economy, food, fashion, design, etc. Not much focus on the manufacturing and product design to achieve circular economy principles is discussed in literature. **[10, 11, 46]**
3. To get more confidence of industry on economic viability and profitability of circular economy principles, there is a need to study and develop quantitative models which can provide more insight into the impact of various factors on circular economy implementation. There are studies in literature, where different modelling techniques are used for studying the impact of circular design on the business models. Very recently, we can see that system dynamics is becoming popular as a modelling technique to simulate and establish quantitatively the impacts of various factors on CE performance. **[11, 12, 20, 21]**
4. In India, with limited resources and increasing population along with increasing consumer base, circular economy is the way forward. The plausible implementation of circular economy principles in Indian economy are predicted to save about 11% and 30% of India's GDP by 2030 and 2050, respectively. In literature almost no emphasis has been laid on research efforts in studying dominant factors impacting the business implications and implementation of circular principles in the Indian manufacturing industry, in general and automobile sector, in particular. **[8, 9, 10, 44]**
5. Circular business models and business model innovation is missing in the Indian automotive sector parlance, there is a lot of recent peer reviewed literature in the European context. **[7, 43, 45, 47, 49, 50]**

SECTION 4: Significance of Study

This study is targeted towards –

1. Developing new models for circular economy implementation in Indian Automotive industry. The circular economy principles of reuse, recycle, reprocess can be applied across the board in

automobile products and process plan starting right from product designing, through product cycle to product discard stage.

2. The results we will obtain will have following impacts –

   i. Provide new direction towards cleaner growth in Indian automotive industry

   ii. With the growth of economy personal transport requirements for Indian population may double by 2030, greener production and consumption can be phenomenal in meeting India's ecological goals.

   iii. Study has potential to open more opportunities of future research in circular economy development in other sectors in India

   iv. We may be able to develop indicators to point out difference between Indian manufacturer's processes and processes followed by foreign MNCs in India.

SECTION 5: Objectives of Study

The objectives of proposed study are enumerated as follows –

1. To analyze the incumbent Production processes and Product cycles of Indian Automobile Sector.
2. To identify the Sustainability Gap's based on the linearity in the processes of Manufacturing, Distribution and Consumption in the Auto Sector.
3. To explore and assess how Circular Economy Principles can be applied to the Automobile Production and Product Cycles in India.
4. To develop System models, facilitating Policy analysis of transformation from linear manufacturing to circular manufacturing of Automobile Products, using suitable modelling techniques.
5. To develop System models, facilitating Policy analysis of transformation from linear manufacturing to circular manufacturing of Automobile Products, using suitable modelling techniques.
6. To establish Holistic and Sustainable Decision-models for the Indian Automobile Sector under futuristic orientation.

7. To examine suitable viable business models and business model innovation to Indian Automobile industry and Policy makers.

SECTION 6: Hypothesis and Conceptual Framework

6.1 Formulation of Hypothesis

Circular Economy is an imperative alternative to the linear models of design prevalent in the Indian Manufacturing Industry. This study can have the following hypothesis –

Ho: There is no significant relationship between circular economy and resource conservation for sustainable development initiatives in Indian Automobile Manufacturing Sector.

H1: There are significant causal linkages between the circular economy principles and optimum resource utilization in product cycle of Indian Automobile Manufacturing Industry.

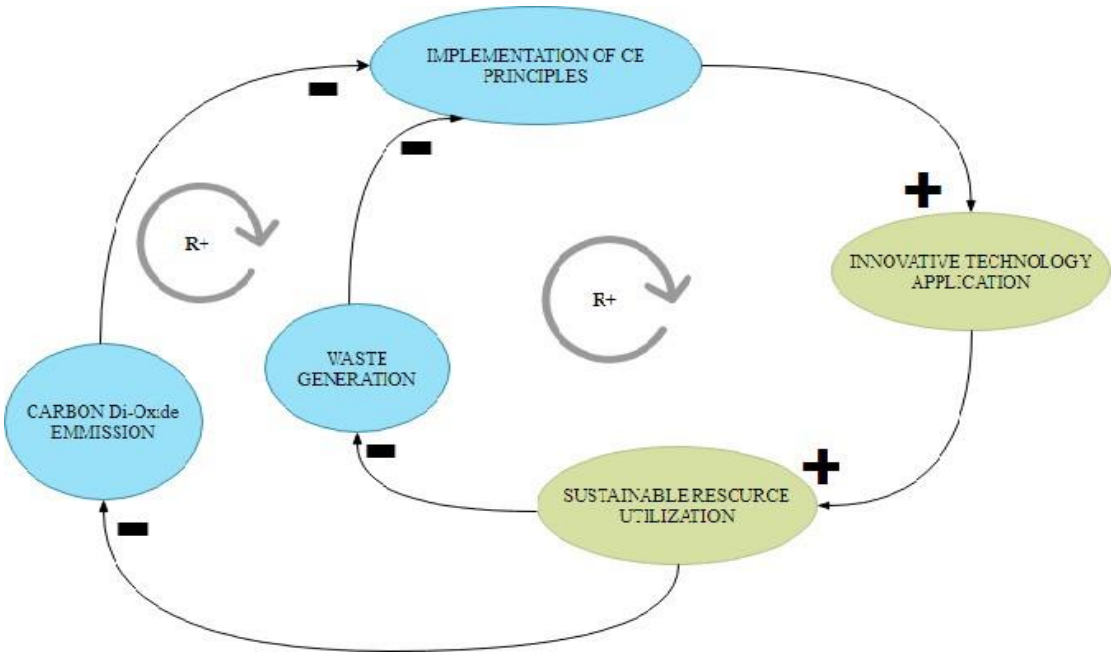
Ho: There is a no linkage between use of circular design principles and reduction in CO_2 emissions and waste generation.

H2: There is a significant positive linkage between use of circular design principles and reduction in CO_2 emission and waste generation.

Ho: There is no direct positive relation between Innovative technological applications and realization of circular economy oriented Sustainable Development Goals (SDG).

H3: There is a direct positive relation between Innovative technological applications and realization of circular economy oriented Sustainable Development Goals (SDG).

6.2 Conceptual Framework



Better and effective implementation of CE principles will require more innovative applications which will in turn lead to sustainable resource utilization, reducing waste and CO_2 emissions which will further increase the motivation to implement CE principle.

SECTION 7: Research Methodology

7.1 Sample Size

For sample size computation Gordon formula is used –

Formulas for Sample Size (SS)	
For Infinite Sample Size	SS = [Z2p (1 − p)]/ C2
For Finite Sample Size	SS/ [1 + {(SS − 1)/Pop}]

Where,

- *SS* = Sample size
- *Z* = Given *Z* value
- *p* = Percentage of population
- *C* = Confidence level
- *Pop* = Population

We have considered the population size of 300, which according to Gordon Formula gives us the sample size of 168.

7.1.1 Sample Breakup

The breakup of respondents will be based on the segment of manufacturing vehicles which we have classified, for the purpose of this study into –

a. Passenger Vehicles
    a. Two Wheelers
    b. Four Wheelers

b. Commercial Vehicles
    a. Trucks
    b. Tractors

7.1.2 Sample Composition

i. Number of companies in NCR – 3 (Maruti, Yamaha, Honda)

ii. Number of companies in Pune – 3 (Fiat, Mahindra, Bajaj, TATA Motors)

iii. Number of companies in Chennai – 2 (Volkswagen, Yamaha)

The sample composition is based on the following parameters –

i. Sales

ii. Turnover

iii. Market Share

iv. Production Size

v. Design Capability

7.1.3 Sampling Technique: Stratified Cluster Sampling

This technique is used when population is divided into various clusters and drawing random samples from all or selected clusters. In other words, population is divided into number of strata of sub-groups and a sample is drawn from each stratum.

7.2 Sources of Data

The researcher seeks to gather both qualitative and quantitative data. The researcher will also make use of the secondary sources of data collection in the form of gathering published materials such as extracts from relevant Journals, Reports, Books and Periodicals covering the present study. Researcher seeks to focus on primary data to analyse the various linear processes used by the automobile companies and reasons behind the linearity to make it more comprehensive and objective- oriented.

7.3 Statistical Tools for Data Analysis

From literature survey, in [11] authors have presented a comparative study on various modeling techniques with the help of multiple case studies, and recommended systems dynamics as the best approach for modeling circular design. Further, in [12] systems dynamics is used successfully to develop new business models for circular economy. These publications and other literature provide enough indicators towards choosing system dynamics as modeling technique for circular economy.

7.3.1 System Dynamics/ Causal Modelling

System dynamics is a powerful methodology to understand and discuss the behavior and structure of complex problems over a time. It applies to dynamic problems arising in complex social,

managerial,

economic, or ecological systems-literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality.[13]

Causal modeling normally consists of sets of equations, indicating a web of causal and non-causal relations among the variables of interest. It models the relations between the properties or characteristics of the system, which are represented by variables.[14]

7.3.2 Software Stella/ Vensim

These are system modeling software platforms [41-42] used to discover, capture and model the dynamic relationship between and among variables and help creating different policy simulation and decision-scenarios.

There are other powerful software tools as well viz. Powersim, Geonamica, Simile, etc. for modeling and simulation. We have considered Stella and Vensim for their rapid prototyping capability, simple interface and extensibility to other platforms.

7.3.3 Correlation Analysis

Correlation analysis analyses the joint variation of two or more variables for determining the quantum of correlation between two or more variables.

7.3.4 T-Test

T-test is based on t-distribution and is considered an appropriate test for judging the significance of a sample mean or for judging the significance of difference between the means of two samples in case of small sample (s) when population variance is not known (in which case is use variance of the sample as an estimate of the population variance).

7.3.5 Chi-Square Test

The Chi-square(x^2) test is applicable in large number of problems. The test is, in fact, a technique through the use of which it is possible for all researchers to: (i) test the goodness of fit; (ii) test the significance of association between tow attributes, and (iii) test the homogeneity or the significance of population variance.

SECTION 8: Chapterization of Thesis

The thesis is proposed to contain the following chapters –

1. Introduction
2. Review of Literature
3. Conceptual Framework, Research Design and Methodology
4. Data Collection and Analysis
5. Results and Interpretations
6. Conclusions and Scope of Future Research
7. Significant Contribution Towards Stakeholders: Customers, Government and Industry
8. Limitations of the Study
9. Bibliography and references

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